CAPILLARITY TESTS ON HISTORIC MORTAR SAMPLES EXTRACTED FROM SITE. METHODOLOGY AND COMPARED RESULTS

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Abstract

Renders and masonry mortars are very exposed to aggressive agents so they are often the object of repair interventions on monuments and ancient buildings. The substitution of ancient lime mortars by new mortars, with different characteristics, has frequently been the cause of accelerated degradation of old masonry walls because of the change on their physical behaviour. The knowledge of physical characteristics of ancient mortars is therefore very important to select repair mortars and to plan adequately the intervention. There is a need to define characterization test methods applicable to irregular, friable samples to assess those characteristics.

In the present paper a test method is described to evaluate water absorption capillarity and some results from Portuguese and Slovenian old mortars are presented and discussed. A comparison with results obtained for new mortars, using the same method and also the method proposed by EN standards helps to extract conclusions of the method's possibilities.

Key Words

Conservation, old mortar, test, capillarity.

1 Introduction

Interventions on ancient buildings often imply repair or substitution of renders. In those cases it is very important to use materials compatible with the old ones. The knowledge about old mortars characteristics is necessary to define the characteristics to accept for repair and substitution materials. Nevertheless, physical and mechanical characteristics are sometimes difficult to assess, because render samples that can be extracted from works are usually small, irregular and sometimes with a low cohesion. Therefore, the direct application of existent standardised tests is seldom possible.

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To obviate this problem some special test methods have to be studied and adapted to old mortar samples collected from site.

Water behaviour is particularly relevant for the whole performance of renders applied on old masonry. In fact renders and repointing mortars must protect the masonry against water, preventing the easy entry of significant volumes of water and promoting their quick drying (VEIGA 2000, VEIGA et al 2001). Besides, water is a major degradation factor for old mortars, because i) it has some capacity of solving mortars constituents ii) it facilitates reactions that promote the formation of weaker elements iii) it increases volume when it turns into ice iv) it solves salts and promotes their movement through the mortar v) it facilitates fixation of biologic colonization.

The study of old mortars characteristics concerning water, namely water absorption and drying behaviour, opens the possibility of trying to formulate new mortars with similar characteristics, consequently with similar expected durability and adequate to protect the same masonry.

A test method was prepared and experimented at LNEC and at the University of Ljubljana to assess the capillarity absorption coefficient of old mortar samples extracted from site. To analyse its liability the test was also applied to some lime mortars prepared in laboratory, with known capillarity absorption coefficients determined by the method proposed by EN 1015-18 (CEN 1999), which is based on the immersion in 5-10mm of water of half prismatic specimens with dimensions of 40 mm x 40 mm x 160 mm. This procedure permitted to compare the results obtained by both methods and to evaluate the correlation between them (figs. 1, 2).

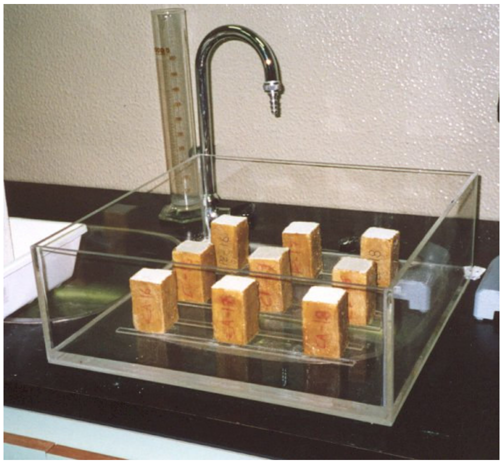


Figure 1 – Standardised capillarity test

Figure 2 – Capillarity test for old mortars

2 Test method

2.1 General

The test developed to evaluate the water absorption by capillarity of irregular, friable, samples is based on the placement of the external face of the specimen in contact with water (instead of in immersion) through the use of wire basket and wet geotextile gauze. It comprises the following phases:

a) Specimens preparation – Three specimens are selected from each sample taken *in situ*, with volumes as similar as possible to those of the half prisms of 40 mm x 40 mm x 160 mm required by the standardised method and with a rather flat face (the external face), which will be put in contact with the water. They are brushed to remove loose particles and biologic colonisation.

b) Test Procedure – The geotextile gauze is wet before the beginning of the test, to avoid the influence of a slow initial absorption of this kind of material. The dry specimen is weighed (fig. 3) and so are the wire basket and the wet gauze (fig. 4). The basket with gauze is placed in a transparent recipient with water, on a lath, taking care that the lower face of the gauze barely touches water and the specimen is placed on the basket (fig. 5). The gauze must not enter the surface of the water more than 2 mm, so that the specimen is in contact with the wet gauze, but not in immersion in water. This situation must be kept during the test.The specimen is weighed periodically, together with the whole wire basket and wet gauze, with intervals of 5 minutes for the first 40 minutes and then at 60, 90, 180, 300, 480 and 1440 minutes. The absorbed water is quantified by the weight increase. After 1440 minutes (24 h), the whole basket, gauze and specimen remain out of water and drying period begins, with periodical weighing operations to determine the water loss.

c) Calculations – The absorbed water is determined through the difference between the weights measured periodically and the initial weight. To measure the specimen irregular surface in contact with water, this surface is placed on a sheet of millimetric paper and its contour is drawn (fig. 6). The obtained area is divided into geometric shapes and the total area is determined as the sum of those regular easily calculated areas. The capillarity coefficient by contact between instants t_1 and t_2 (Ccc_{t2-t1}) is then calculated through the following expression: $Ccc_{t2-t1} = (M_2-M_1)/(\sqrt{t_2}-\sqrt{t_1})$.

Figure 3 – Weighing the dry specimen

Figure 4 – Weighing basket and gauze

Figure 5 – Placement in a recipient with water

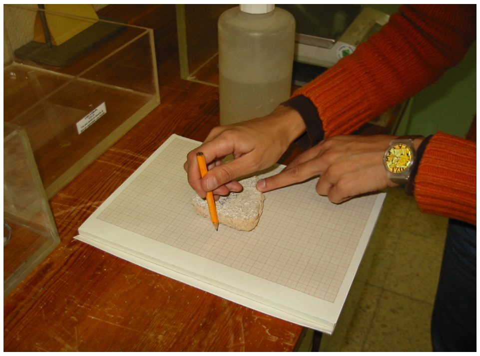


Figure 6 – Measurement of the absorption area

2.2 Samples description

Samples of renders from five monuments were included in the study and some specimens of each one were subjected to the water absorption test adapted for irregular, friable samples. Simultaneously, six different lime based mortars prepared in laboratory with known capillarity coefficients determined by the standardised method were also subjected to the same test. Those laboratory prepared mortars were used to evaluate the correlation between the standardised test and the proposed one.

The main characteristics of laboratorial mortar specimens are synthesized on table 1 and the monuments and main characteristics of the tested old mortar samples are summarized on table 2.

Table 1 Characteristics of laboratory prepared mortars used for validation.

Mortar	Composition		Mass of the specimen (g)	Characteristics at 28 days		
	Volumetric dosage	Constituents		Density (kg/m^3)	Compressive resistance (MPa)	Capillarity coefficient $C_{(90-10)}$ ($kg/m^2.h^{1/2}$)
L	1:3	Air lime : river sand	456	1780	0.6	11.5
L-Cl	1:0.2:2.8	Air lime : clay : river sand	463	1810	0.9	10.5
Lls	1:3	Air lime : mixed sand from the Lisbon region	232	1870	0.2	10.2
AH	1:3	Artificial Hydraulic lime : mixed sand from the Lisbon region	232	1890	3.1	14.6
L-AH	1:1:6	Air lime : artificial hydraulic lime : mixed sand from the Lisbon region	225	1780	0.5	3.6
L-Ce	1:1:6	Lime : cement : mixed sand from the Lisbon region	244	1760	2.9	9.6

Table 2 Characteristics of samples collected in situ.

Mortar	Monument		Characteristics		
	Type	Age	Composition	Average specimens mass (g)	Compressive resistance (MPa)
CSP1	Castle – joints (South Portugal)	XII century	Light brown lime mortar with white lime grains, siliceous sand and clay	248	Not determined
CSP2				289	1.61
CSP3				356	Not determined
AWP	Arab Wall – joints (South Portugal)	VIII century	White lime mortar, very hard, with white lime grains and small shells	147	Not determined
CLis	Convent in the Lisbon area - render	XVI century	Light brown lime mortar, very hard, with white lime grains	955	4.71
CSI1R	Castle-render (South-East Slovenia)	XIII century	Light brown lime render mortar with dolomitic crushed aggregate and siliceous sand. Degradation process is visible by chemical analysis (SANTOS SILVA 2004)	178	3.69
CSI2J	Castle-joint (South-East Slovenia)	XIII	Light brown lime joint mortar with dolomitic crushed aggregate and siliceous sand. Degradation process is visible by chemical analysis (SANTOS SILVA 2004)	187	7.28
CSI3R	Castle-render (South-East Slovenia)	XVI	Light brown lime render mortar, with white lime grains, dolomitic crushed aggregate and siliceous sand	235	Not determined
CSI4P	Castle-plaster (South-East Slovenia)	XVI-XVIII	White lime plaster mortar with white lime grains dolomitic crushed aggregate and siliceous sand	332	Not determined
RSI5J	Roman settlement-joint (South Slovenia)	I	White lime joint mortar, very hard, with white lime grains, aggregate from Sava river and clay bricks particles	268	Not determined
WSI6R	Rendered clay brick wall for field studies (Ljubljana)	XX	White lime mortar (1:3) made from traditionally produced lime putty and siliceous sand	541	2.10

2.3 Test results

Tables 3 and 4 and graphics 1 to 9 present the test results.

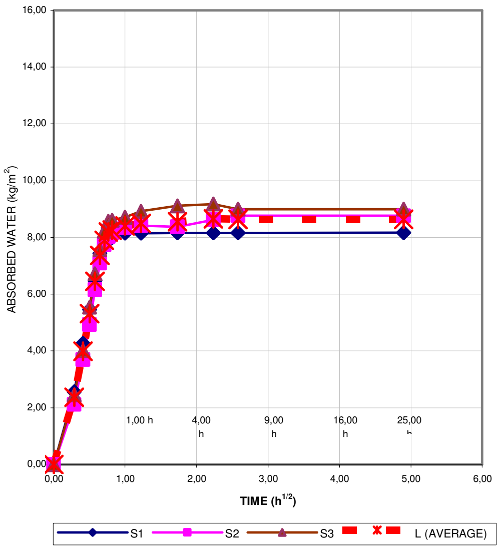
Table 3 Capillarity Coefficients of laboratorial mortars by immersion (C) and by contact (Ccc) for comparison

Mortar	Area in contact with water (mm^2)	Specimen mass (g)	Area/mass (mm^2/g)	Capillarity coefficient (kg/m^2.h$^{1/2}$)			
				At 5 min	Between 90 and 10 min		
				Ccc5	Ccc90-10	**C90-10**	Factor C/Ccc
L	6400	456	14	8.2	5.5	**11.5**	2.1
L-Cl	6400	463	14	9.5	5.3	**10.5**	2.0
Ls	3200	232	14	21.3	4.1	**10.2**	2.5
AH	3200	232	14	11.9	4.5	**14.6**	3.3
L-AH	3200	225	14	20.2	1.3	**3.6**	2.9
L-Ce	3200	244	13	15.2	3.7	**9.6**	2.6

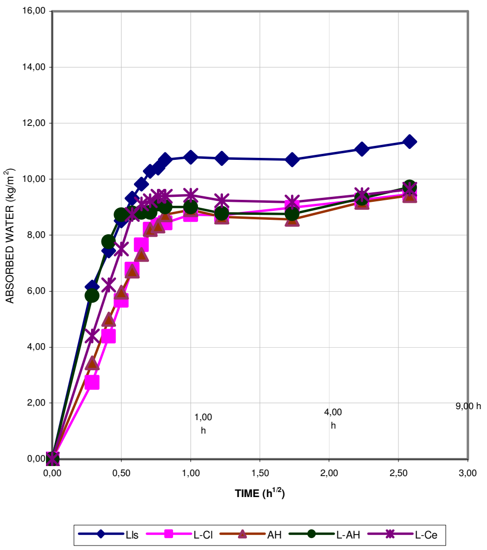
Table 4 Capillarity Coefficients of ancient mortars by contact

Mortar	Area of specimens in contact with water (average) (mm^2)	Specimens mass (g)	Area/mass (mm^2/g)	Capillarity coefficient (kg/m^2.h$^{1/2}$)		
				Ccc5	Ccc90-10	Ccc24
CSP1	6005	248	24	3.3	3.9	2.1
CSP2	4658	289	16	7.1	7.0	2.2
CSP3	7081	356	20	4.6	3.7	2.1
AWP	2091	147	14	7.4	5.3	1.9
CLis	13072	955	14	2.7	1.8	1.0
CSI1R	4566	178	26	4.7	1.2	0.6
CSI2J	3432	187	18	5.5	1.6	0.6
CSI3R	6145	235	26	4.8	3.7	1.5
CSI4P	10527	332	33	11.8	1.1	1.1
RSI5J	5571	268	21	17.8	2.9	1.9
WSI6R*	14042	541	26	5.9	1.7	0.8

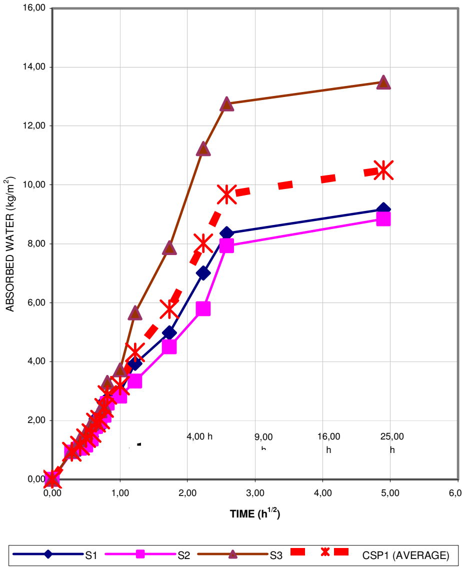
* about five years old lime render from clay brick wall for field studies



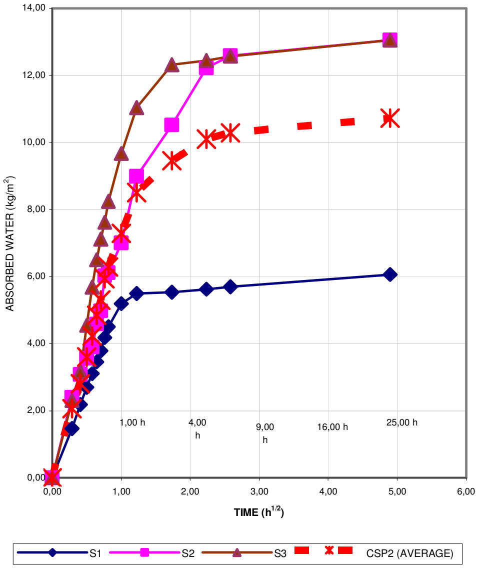
Graph 1 – L mortar



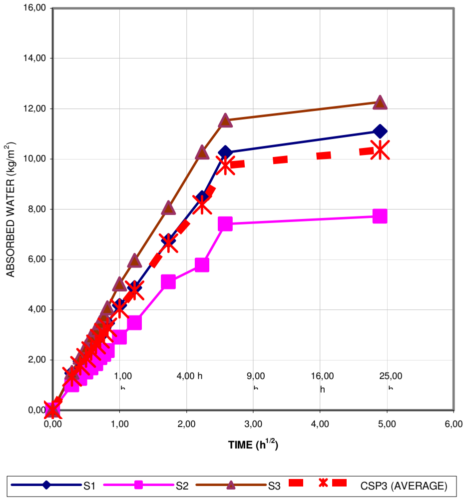
Graph 2 – Other laboratorial mortars



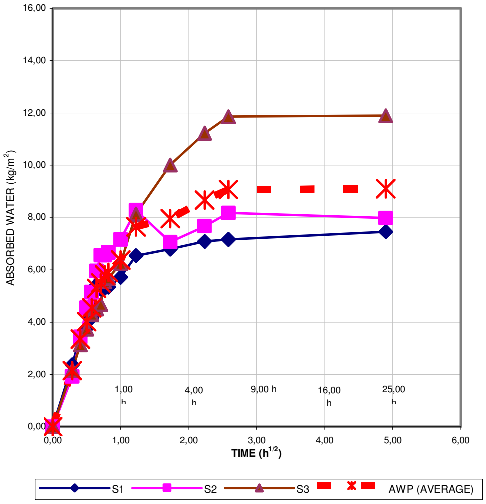
Graph 3 – CSP1 mortar



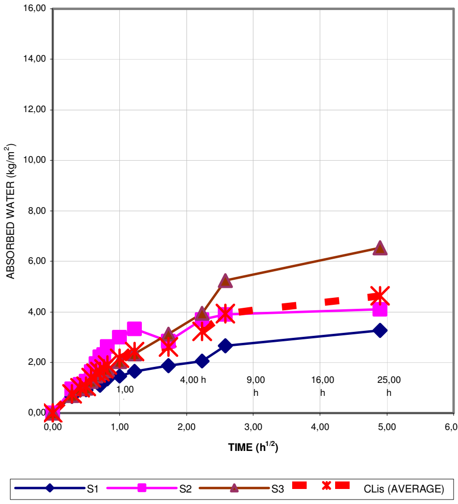
Graph 4 – CSP2 mortar



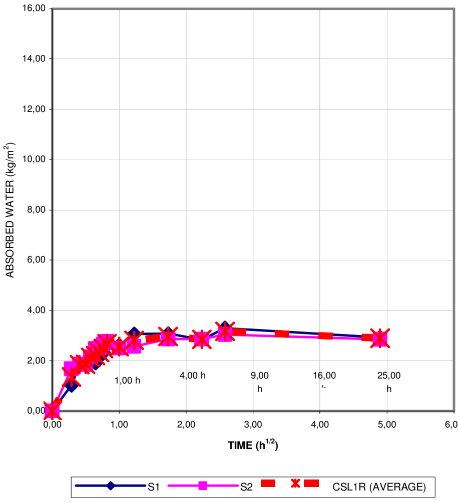
Graph 5 – CSP3 mortar



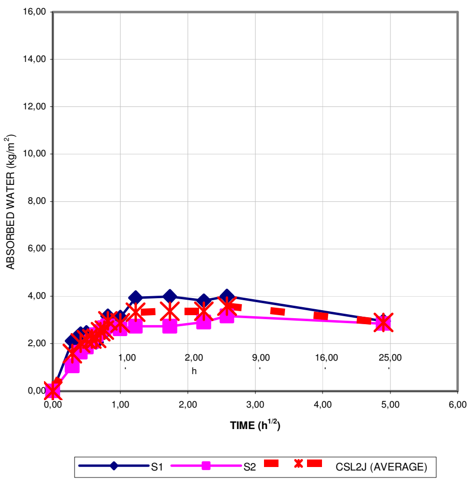
Graph 6 – AWP mortar



Graph 7 – CLis mortar



Graph 8 – CSL1R mortar



Graph 9 – CSL2J mortar

3 Conclusions

3.1 Validity of the method

The comparison between capillarity coefficients obtained by the contact method and capillarity coefficients determined by the standardised immersion method for laboratorial mortars shows that there is some correlation, with a ratio C/Ccc varying from 2 to 3.3. This variation seems acceptable, considering that both methods have some variability. In particular, capillarity of recent lime mortars changes quickly with age and the consequent increase in the degree of carbonation. So there is a possibility that when the new test was applied to those samples, some time after the accomplishment of the standardised one, they had already actually reduced slightly their capillarity.

Dispersion of results for the different specimens of the same mortar, which can be evaluated by graphics 1 and 3 to 9, is not too high, considering the variability of several factors.

The comparison between compressive resistance and capillarity of old mortars seems also consistent, showing that generally to higher strength (mortars from a Slovenian Castle and from a Convent in the Lisbon area) corresponds lower capillarity during the first minutes as expected. Similarly, mortars with lower strengths (mortars from a Portuguese Castle and from an experimental Slovenian wall) show higher early capillarity.

To increase the liability of the method it seems important to have a more or less constant area/volume ratio, for example about 25 m^{-1}, similar to that used for new mortars tests. Because the weight of an old mortar is much easier to measure than its volume and it implies a lower risk of deterioration, that relation can be substituted by the relation area/weight, which is a sufficient indicator of the shape similarity. The volume of the samples, or their weight to simplify, must also be similar. 250 g might be a good average mass to consider (similar to the half prism of 40 x 40 x 160 mm used for the standardised test). In the present study these rules were not entirely respected, especially for the first tested samples.

3.2 Analysis of the results for old mortars

The stabilisation of water absorption happens much before 24 h, consequently Ccc24 is meaningless for traditional lime mortars, or at least it doesn’t show an absorption rate.

The old lime mortars studied present capillarity coefficients rather similar to new lime mortars between 90 and 10 minutes. Nevertheless, they have much slower absorptions during the first minutes, as is shown by Ccc5 significantly lower than new mortars’ and rather close to Ccc90-10. This means, apparently, that the absorption rate of old mortars remain almost constant during the first 90 minutes, while new mortars have a much higher rate of absorption during the first minutes and than stabilize. The graphics 1 to 9 confirm this effect. It is suggested by literature that a high initial absorption ratio indicates a weak mortar, with larger pores, more subject to deterioration and consequently less durable (THORBORG 1997). Determinations of porosimetry must be performed to study these differences. On site behaviour confirms those conclusions about durability, as still existent old lime mortars, especially in monuments and important civil and military buildings, show a higher resistance than lime mortars recently applied. The reason for this may lay on the careful application, some small but influent difference in constituents, or simply on the evolution through time, due to complete carbonation and possibly other slow reactions.

3.3 Utility of the method

When it is not possible to use the standardised method, the described methodology seems to furnish a definite possibility of assessing the capillarity of old mortars, with resource to samples extracted from site. As referred before, this characteristic, in particular the evolution of absorption along time, is an important indicator of the resistance to water effects and consequently of durability of the mortar. These results must be complemented by mercury porosimetry to understand the causes of the differences obtained. On the other side, the verification of a quick drying is very important to avoid damage to the wall due to a long retention of water inside it.

In conclusion, the test presented has an expressive utility to old mortars study and conservation and to the selection and preparation of new compatible mortars. The fact that there are not so many tests to assess the physical characteristics of old mortars increases its interest.

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